Design and Implementation of a Groundwater Monitoring System for Faskin Ranch, Hudspeth County, Texas

This report is presented as a partial requirment for a
Bachelor's of Science in Hydrogeology

The University of Texas at Austin

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Abstract

I designed and installed two databases that will be used for the monitoring data from the Texas Low-Level Radioactive Waste Facility. The databases were designed to meet two criteria: 1) easy access to data and the references from which they had been collected and 2) easy input of monitoring data from wells on and off the facility site for comparison of background levels. I also designed a protocol data sheet to be coupled with the hydrologic monitoring database. Data from these sheets can be easily recorded and subsequently inputted into the database for comparison of data, such as water levels, in order to show trends in the data as a result of operation of the waste site.

Additionally, I constructed maps of the low-level facility area and the areas surrounding the site. These maps included: an area base map, and maps of the potentiometric surface, ground-water flow paths, chemical facies, and total dissolved solids concentrations. These maps can be used as background references for water levels, dominant chemical facies, and total dissolved solids concentrations, and later refined to portray any changes in these values.

Finally, I was also involved with assessing how the Panhandle Groundwater District #3 assigns water level depletions to properties and developing a more rigorous method for doing this. This involved examining hydrographs from several counties in the Panhandle to determine large fluctuations in water levels from wells and the relationship between the assigned depletions and the actual measured and average levels that have been measured and assigned by the PGWD #3.

Introduction

From September, 1995 to June, 1996, I worked at the Bureau of Economic Geology. My assignment with the Low-Level Radioactive Waste Facility research group was to design and implement a monitoring database for the proposed Texas Low-Level Radioactive Waste Facility in Hudspeth County, Texas. This study was part of my hydrogeology internship requirement for a Bachelor's of Science degree in Hydrogeology from The University of Texas at Austin. In addition to work with the low-level group, I also worked with Robert Mace, studying water level depletions in the Ogallala Aquifer in the Texas Panhandle. This report is included as Appendix A.

Hydrogeologic investigations of the proposed Texas Low-Level Radioactive Waste Disposal Facility in Hudspeth County, Texas, continue on both regional and site-specific scales. The activities detailed in this report include the design and implementation of a monitoring system for the operational, closure, and post-closure periods of the facility. An assessment of water properties and chemical constituents was made using well data available from in and around the site. This will serve as a reference datum for comparison with future monitoring data once the site is operational.

Location and Hydrogeology

Four principal aquifers are present Hudspeth County: the Diablo Plateau aquifer consisting of Cretaceous limestones, marls, shales, anhydrites, and sandstones exposed on the Diablo Plateau; the Hueco Bolson silt and sand aquifer; the Rio Grande alluvial aquifer; and the Bone Spring-Victorio Peak Limestone aquifer (Geologic Map of Texas, Marfa Sheet). Hydrologic investigations such as Kreitler et al., 1987 and Darling et al., 1994 for the county have become increasingly more important because of the proposed low-level radioactive waste facility site. These studies evaluate water level, isotopic, geochemistry, total dissolved solids, and monitoring well data to determine recharge and discharge points, chemical facies, and water flow paths in the county. Another important hydrologic issue affecting Hudspeth County is high water use. Pumpage rates and decreasing availability of good quality water are diminishing the county's usable water supply.

Three groundwater basins, defined by surrounding watersheds and groundwater divides, divide southern Hudspeth County. These are: the Northwest Eagle Flat watershed, the Southeast Eagle Flat watershed, and the Red Light Draw watershed. The Northwest Eagle Flat watershed encompasses the Blanca Draw watershed, including Grayton Lake, located east of the facility site, and Faskin Ranch. A surface water divide bounding Eagle Flat Draw defines the Southeast Eagle Flat watershed boundary. The Red Light Draw watershed includes Red Light Draw, its source areas, and parts of the Rio Grande alluvium aquifer (figures 1 and 2) (Darling, et al., 1994).

Recharge and Discharge

Kreitler and others (1987) determined that recharge occurs on the Diablo Plateau and parts of the Hueco Bolson, primarily through infiltration of runoff in beds of ephemeral streams, arroyos, or during flash floods. Karst features such as fractures and sinkholes account for other areas of recharge and allow easy access tot the subsurface for infiltrating surface waters. I used water elevation data to construct a potentiometric surface map of the low-level site and the surrounding watersheds (figure 3). This map indicates that groundwater recharges in the Diablo Plateau and parts of the Hueco Bolson and discharges to the Rio Grande River and the Salt Basin. This assumes that the Diablo Plateau, Hueco Bolson, and Rio Grande aquifers are hydrologically connected. Recharge in the bolson deposits is low because of large amounts of runoff, low permeability sediments, and a high evapotranspiration rate (Mullican and Senger, 1992).

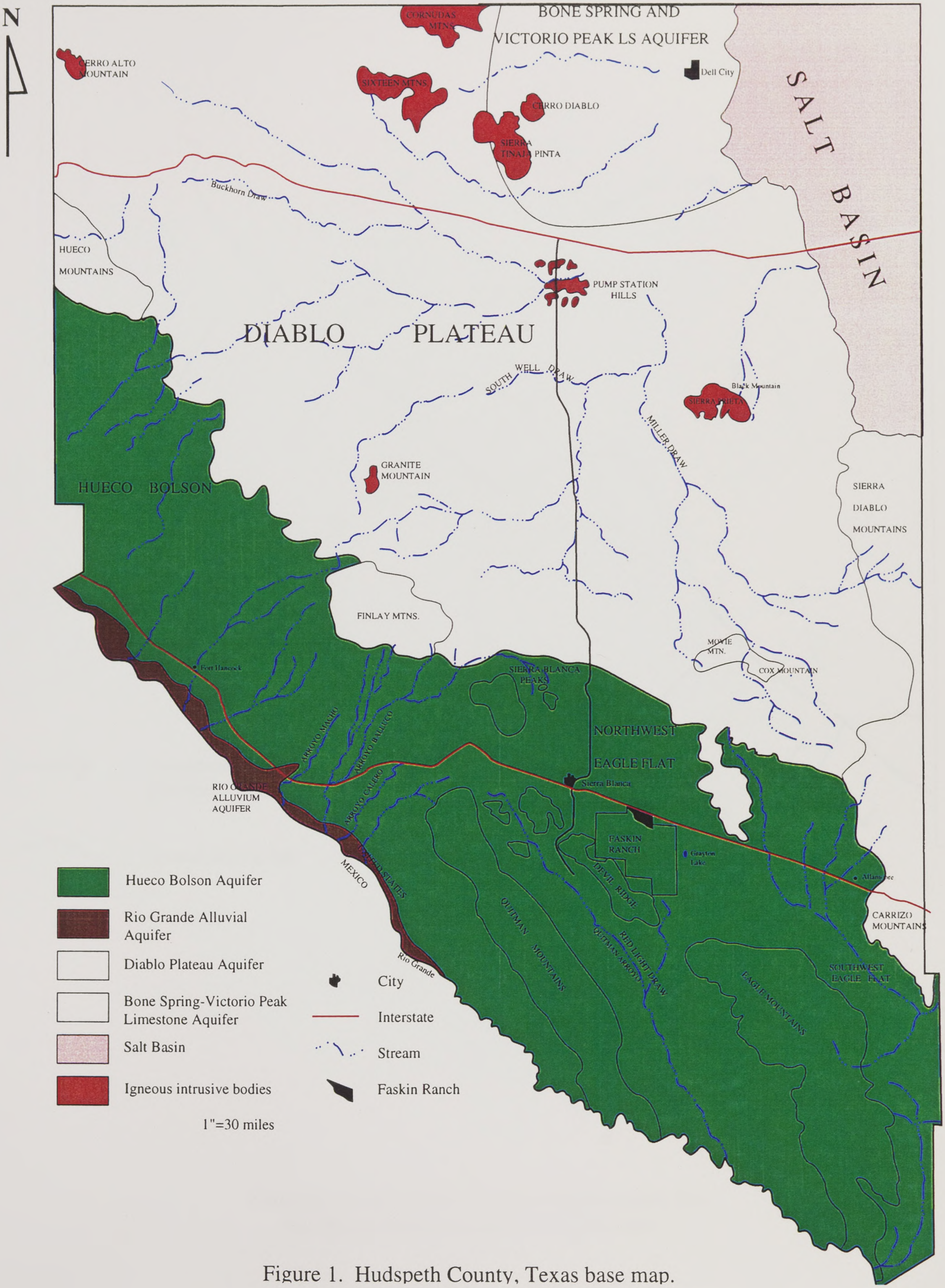

Figure 1. Hudspeth County, Texas base map.

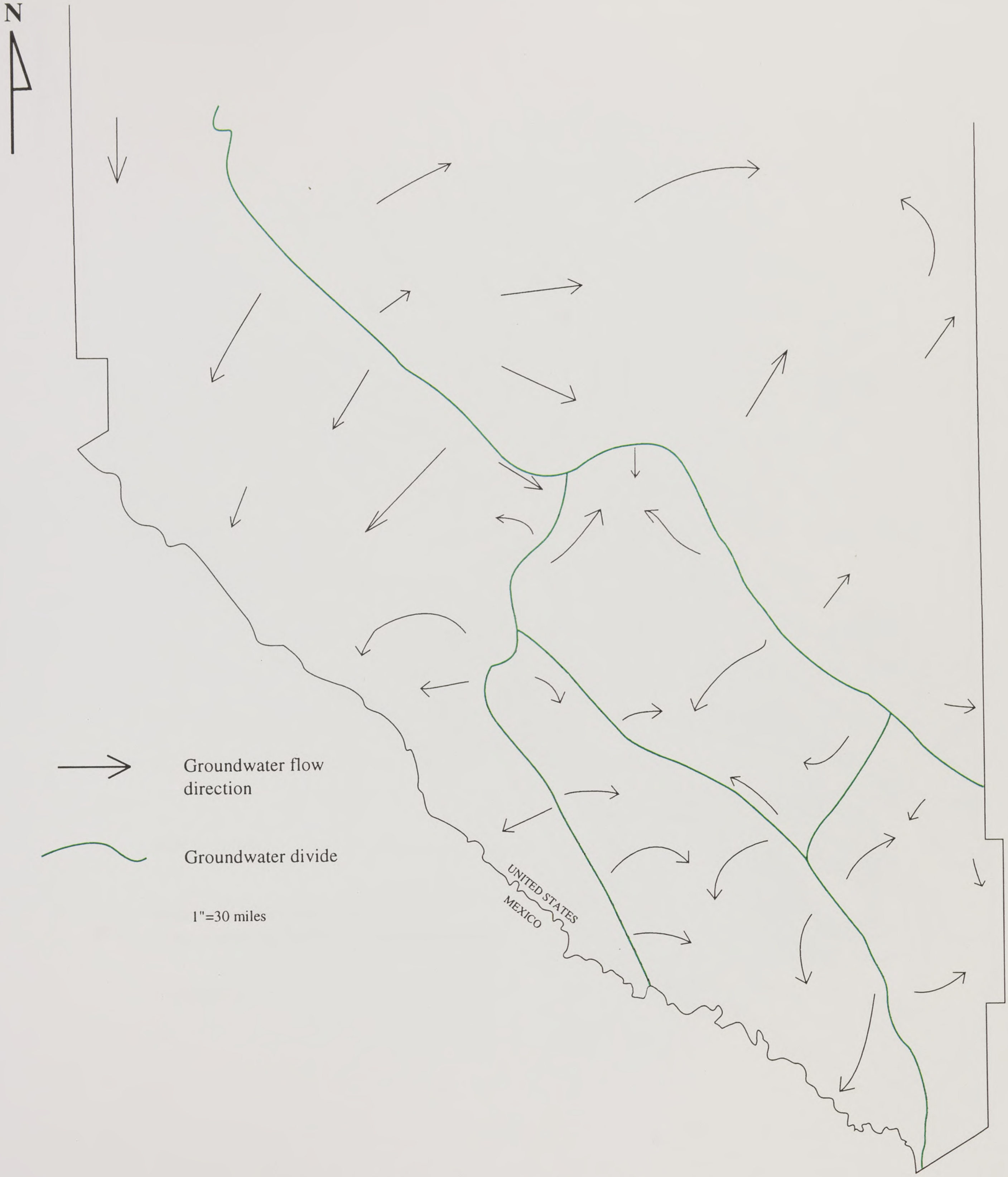

Figure 2. Groundwater divides and flow paths for the Faskin Ranch site and surround areas.

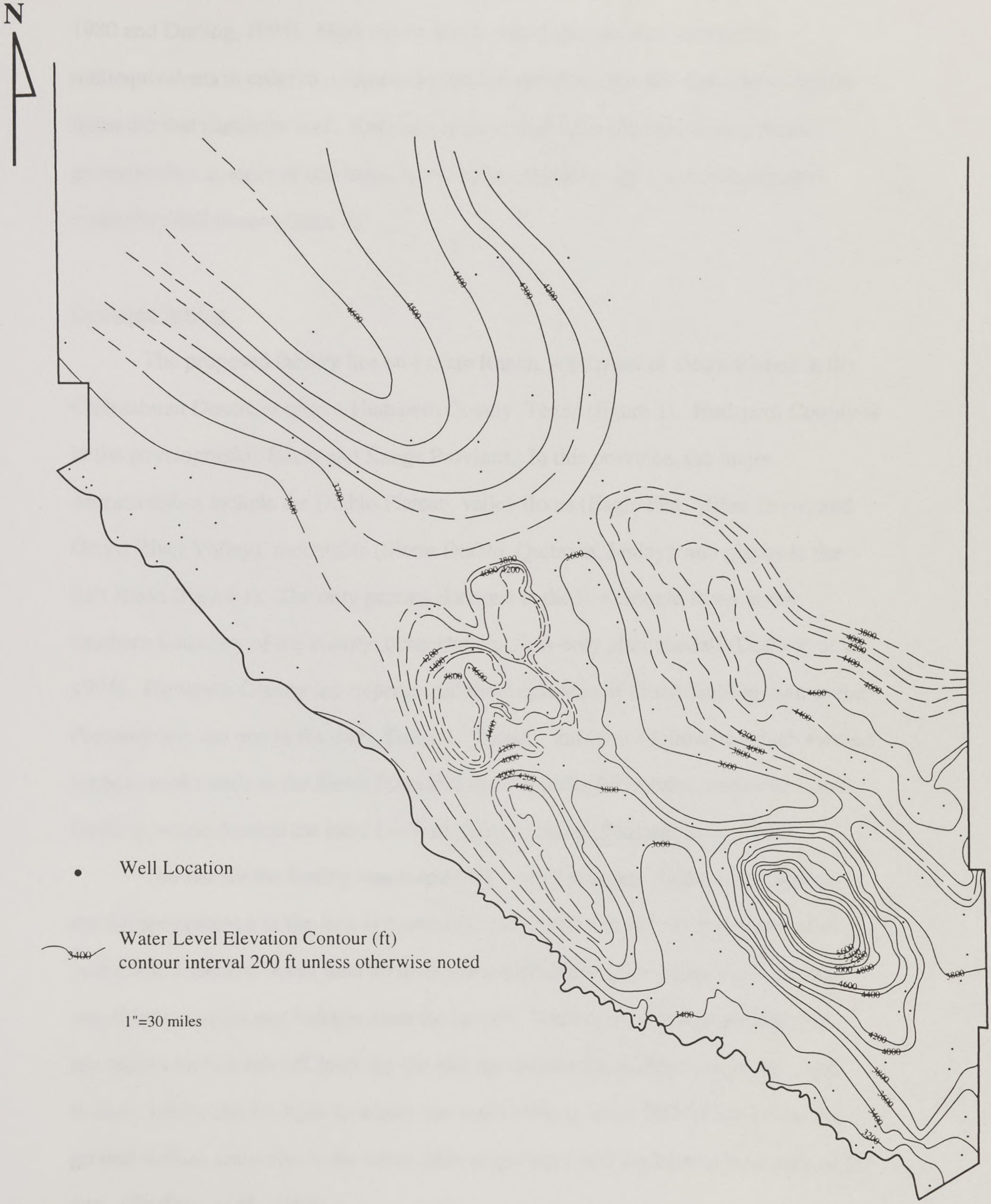

Figure 3. Potentiometric surface map of the low-level facility area and the surrounding watersheds.

Chemical data have been collected for wells in Hudspeth County (Gates, et al., 1980 and Darling, 1994). Mg/l values for chemical species were changed to milliequivalents in order to compare the species and determine the dominant chemical facies for that particular well. Recharge areas contain calcium bicarbonate facies; groundwaters in areas of discharge have sulfate, chloride, and sodium dominated hydrochemical facies (figure 4).

Geologic Setting

The proposed facility lies on Faskin Ranch, southwest of Sierra Blanca in the Chihuahuan Desert, southern Hudspeth County, Texas (figure 1). Hudspeth County is in the physiographic Basin and Range Province. In this province, the major characteristics include the Diablo Plateau, valley floors (Eagle Flat, Miller Draw, and Green River Valley), mountains (Sierra Diablo, Quitman, Finlay), and playas in the Salt Basin (figure 1). The only perennial stream is the Rio Grande River at the southern boundary of the county; other streams flow only after rainfall (Darling, et al., 1994). Hudspeth County has experienced three episodes of thrust faulting, two in the Precambrian and one in the early Tertiary. Igneous intrusions followed, which formed igneous peaks such as the Sierra Pinta and the Cornudas Mountains, and extensional faulting, which formed the local basin and range setting (Darling, et al., 1994).

The site for the facility was chosen for several reasons: 1) the arid climate--annual precipitation in the area is between 0.110-0.430 mm yr^{-1}, 2) the presence of low permeable sediment--more than 60 m of low permeability clays below the ranch site would help contain any leakage from the facility, 3) relatively flat topography--this minimizes surface run-off from the site and run-on into the facility area (Larkin and Bomar, 1983), and 4) depth to water--the water table is about 209-229 m below the ground surface and a rise in the water table might not reach the bottom boundary of the site. (Darling, et al., 1994).

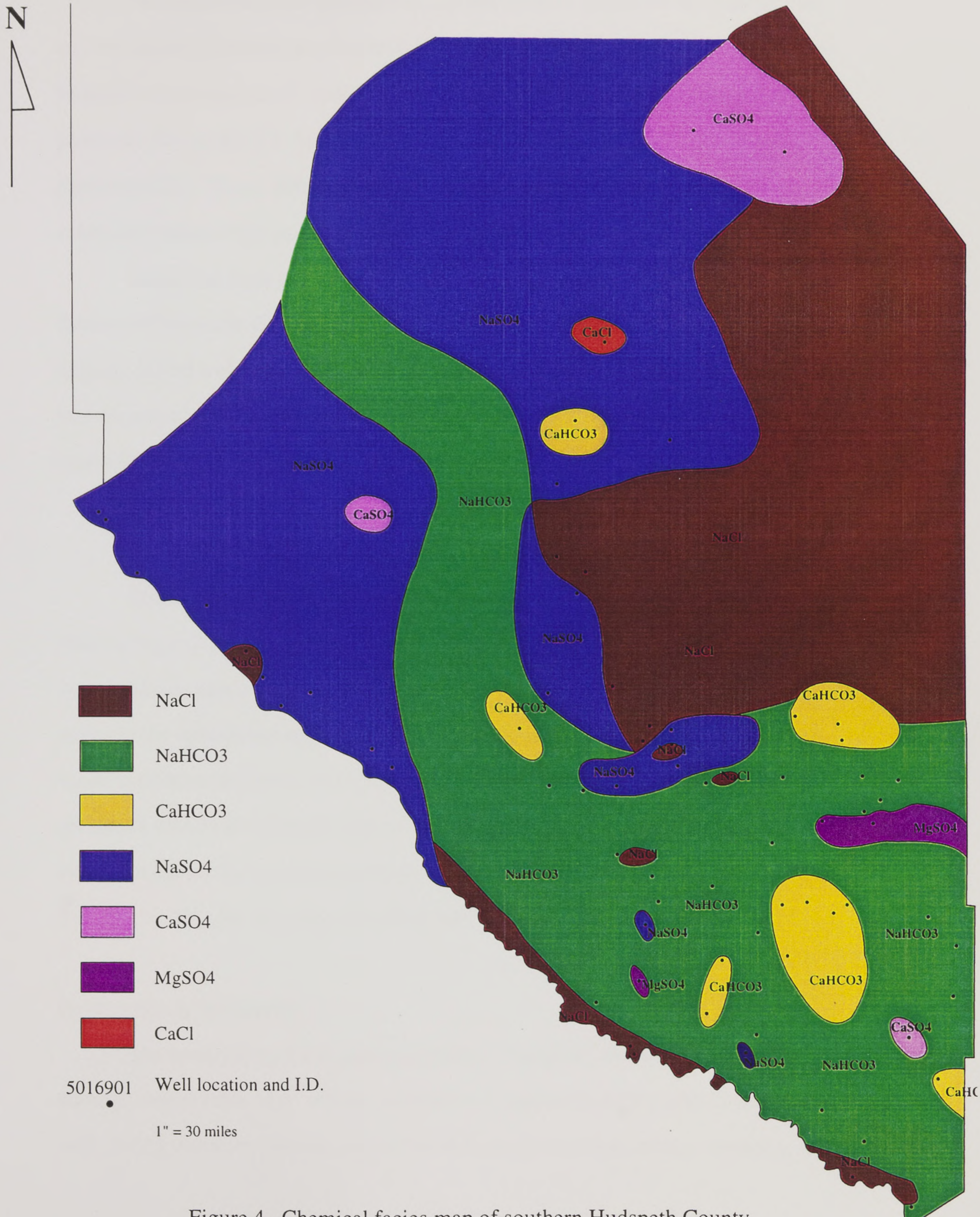

Figure 4. Chemical facies map of southern Hudspeth County (from Mullican, et. al, 1992 and Darling, et. al, 1994).

Protocol Databases

I entered initial hydrogeologic and hydrochemical conditions for both the site and the region around the site into two databases, one hydrogeologic database and one hydrochemical database, for use during monitoring activities at the facility. In particular, the database is designed for future transfer into Geographic Information Systems (GIS). These spreadsheets allow comparison of past and present data to determine changes that have occurred during monitoring.

Data come from the Texas Water Development Board (TWDB), from the Bureau of Economic Geology (BEG) well records for Hudspeth County, and from recently drilled wells by the BEG. I inputted the hydrogeologic and hydrochemical data into two separate databases that will serve as the reference hydrogeologic and hydrochemical databases for future monitoring.

Monitoring Program

There are currently seven operational groundwater monitoring wells and one monitoring well under construction on Faskin Ranch. Reasons for implementing a hydrogeologic monitoring program are to 1) extend the life of production pumps, 2) maintain the operational status of monitoring wells, and 3) provide permanent surface water to different locations on Faskin Ranch. The hydrogeologic monitoring will be combined with hydrochemical monitoring, which will test for specific radiological emissions (gross alpha and gross beta) and inorganic (Al, HCO_3, B, Ca, Cl, Fe, Mg, Mn, Pb, Si, SO_4, Zn, and total dissolved solids (TDS).

Hydrogeologic Monitoring

The hydrogeologic information database I designed includes the following entries: well number, date of well measurement, person or agency who measured the well, casing diameter, geologic age of the well-penetrated rock, surface elevation, total well depth, groundwater levels, production rates of the wells, and water elevation. Graphs made from monitored water depths and elevations versus time after facility implementation will compare trends in water level declines or increases. This may indicate whether the construction and operation of the facility impact hydrogeologic standards established through background testing. Table 1 is an example page from the hydrogeologic monitoring database.

The composite potentiometric surface map (figure 3) also shows Faskin Ranch enclosed by a 3600 ft (1097 m) contour line, indicating a closed groundwater basin in the area of the proposed facility. Preliminary data from a new monitoring well located between the southeast border of Devil Ridge and the northwest border of the Eagle Mountains is compatible with the concept of a hydrologically-closed basin in which groundwater flows from high hydraulic head to low hydraulic head (figure 2).

Monitoring Well Production

The BEG is working with the Texas Low-Level Radioactive Waste Disposal Authority's technicians on how to produce/pump the wells. This production process will entail specific procedures and schedules for regular production for each monitoring well. Individual protocols have been established for each well because of the varying hydrologic characteristics between the wells. The initial goal is to pump the wells for a minimum of 2 to 8 hours, once a month, for one year. Pumping will occur at each well once a month. During the months of quarterly water sampling, wells will be pumped the week prior to the sampling. Evaluation of the monitoring program after the first year will determine if well production should increase or decrease. Figure 5 is an example of a protocol data sheet I designed for monitoring technicians to record the monitoring parameters during each well pumping period. The Authority's field office will keep original records, and the BEG will receive copies on a monthly basis.

Well I.D.	Date collected	Collected by	Well depth (ft)	Casing diameter (inches)	Geologic formation age	Surface elevation (ft)	Depth to water (ft)	Water-level elevation (ft)	Data code
YM-7A	6/23/92	BEG	882	8	K	4271.0	651.0	3620.0	BD-4
YM-8	12/17/92	BEG	1018	8	K	4316.0	667.6	3648.4	BD-3, BD4
YM-8	1/15/96	BEG	1018	8	K	4320.5	670.0	3650.5	
YM-8	1/30/96	BEG	1018	8	K	4320.5	670.2	3650.3	
YM-18	6/26/93	BEG	835	8	K	4376.0	751.1	3624.9	BD-A
YM-18	1/15/96	BEG	835	8	K	4378.2	753.2	3625.0	
YM-18	1/29/96	BEG	835	8	K	4378.2	754.2	3624.0	
YM-19	1/13/93	BEG	822	8	K	4350.0	725.7	3624.3	BD4
YM-19	6/26/93	BEG	822	8	K	4350.0	725.0	3625.0	BD-A, BD4
YM-19	1/15/96	BEG	822	8	K	4351.9	727.0	3624.9	
YM-19	1/29/96	BEG	822	8	K	4351.9	727.6	3624.3	
YM-63	6/26/93	BEG	920	8	K	4359.0	733.3	3625.7	BD-4
YM-63	1/15/96	BEG	920	8	K	4360.9	735.2	3625.7	
YM-63	1/29/96	BEG	920	8	K	4360.9	736.3	3624.6	
YM-105	1/15/96	BEG	1005	8	K	4374.5	744.8	3629.7	
YM-105	1/29/96	BEG	1005	8	K	4374.5	737.3	3637.2	
YM-106	1/15/96	BEG	566	8	K	4191.0	443.5	3747.5	
YM-106	1/29/96	BEG	566	8	K	4191.0	446.7	3744.3	
48-62-TEX	1/15/96	BEG	1250	8	K	4575.0	842.0	3733.0	
48-62-TEX	7/8/92	BEG	1250	8	K	4575.0	842.0	3733.0	BD-4
48-63-302	8/30/72	TDWR	602	8	pCamb.	4506.0	354.4	4151.6	TDWR-43
48-63-601	1/1/59	OWNER	899	6	K	4391.0	700.0	3691.0	TDWR-44
48-63-802	7/10/72	TDWR	124	5	K	4314.0	120.7	4193.3	TDWR-44
48-63-803	7/10/72	TDWR	213	8	K	4532.0	24.7	4507.3	TDWR-44
48-63-901		TDWR	1000	6	K	4540.0	900.0	3640.0	BD-W
48-63-902	6/8/73	TDWR	238	6	QTal	4757.0	227.0	4530.0	TDWR-44
48-64-201	9/12/72	TDWR	226	8	pCamb.	4504.0	143.8	4360.2	TDWR-44
48-64-301	8/24/72	TDWR	200	5	pCamb.	4676.0	156.0	4520.0	TDWR-44
48-64-302	9/12/72	TDWR	193	6	pCamb.	4560.0	157.8	4402.2	TDWR-44
48-64-302	1/11/93	BEG	193	6	pCamb.	4560.0	142.0	4418.0	BD-2, BD3, BD2
48-64-501	4/3/73	TDWR	477	6		4388.0	229.6	4158.4	TDWR-44
48-64-501	3/15/94	BEG	477	6		4388.0	141.0	4247.0	BD-2

BEG=Bureau of Economic Geology
TDWR=TX Water Development Board
BD=Bruce Darling Field Notebooks
K=Cretaceous
pCamb=pre Cambrian
QTal=Quaternary alluvium

Table 1. Example of hydrogeologic data.

WELL NUMBER YM-8

WELL DEVELOPMENT PROTOCOL
This well will be developed twice a month. In months when quarterly samplings are scheduled, well development will occur the week before sampling.
1. Check generator to insure adequate amount of diesel for 2 hours of operation, then start generator.
2. Check to make sure valve in flow line is open.
3. Turn pump on, record starting time, and adjust discharge rate to approximately 15 gpm (20 seconds per 5 gallon bucket).
4. After this is achieved, pump well for 2 hours.
5. Fill storage tank then discharge water to surface.
6. At the end of 2 hours, remeasure and record the discharge rate, turn off pump, and record end time.
7. Make sure transducer is plugged into the datalogger and secure well.

Start Date ______________________ End Date ______________________

Start Time ____________________ AM/PM End Time ____________________ AM/PM

Initial Discharge Rate (gpm) ________________ Final Rate (gpm) ________________

Beginning water level in storage tank (ft) ______________________________

Ending water level in storage tank (ft) ______________________________

Comments ____

____

Monitoring Technician ______________________ Date ______________________

Total Depth 1018 ft Surface Casing Depth 85.0 I.D. 8"

SWL (1/96) 670.00 ft Land Surface Elevation 4318.40 ft

Screened Interval 200 ft I.D. 6" Reference Elevation Top of casing

Pump Depth 969.0 ft Water Level Elevation (1/96) 3651.51 ft

Figure 5. Protocol data sheet.

Rather than discharge the water produced from the pump tests to the ground surface, several 800-gallon stock tanks placed closely to the wells will hold the pumped water. This establishes a permanent source of water at multiple locations on Faskin Ranch. During periods of drought, the wells can be pumped more frequently to keep water in the tanks as a source of water for livestock.

In addition to well production, the hydrogeologic monitoring will also include installing pressure transducers in the eight monitoring wells to establish long-term water level trends and barometric efficiencies. It will also be necessary for the monitoring technicians to change out the data loggers on a monthly basis.

Chemical Monitoring

Accurate background levels of inorganic ions and compounds (Al, HCO_3, B, Ca, Cl, Fe, Mg, Mn, Pb, Si, SO_4, Zn, and TDS) and gross gamma and gross beta must be documented in order to detect changes in these concentrations that can be hazardous to human health and the environment. According to Susan Jabonski at the TLLRWA, rocks, plants, animals, etc., all naturally emit gamma and beta rays. Therefore, in order to accurately detect subtle changes in radionucleide concentrations due to the operation of the facility, it is necessary to have a thorough understanding of background radionucleide levels well in advance of site operation. Therefore, air, water, vegetation, and soil and sediment chemical monitoring began in September, 1994.

Ion concentrations, pH, and temperature are the basis for the initial hydrochemical database (table 2). The TLLRWA will eventually add gross alpha, gross beta, tritium, carbon-14, and radon data to the hydrochemical database.

The schedule for well monitoring has been set up as follows: 1) three of the wells will be sampled semi-annually for inorganic ion concentrations, 2) six wells will be sampled annually for inorganic ion concentrations, 3) surface water samples will be

Well I.D.	Date collected	Data taken by	pH	Temp. ° C	SiO2 mg/l	Na mg/l	K mg/l	Mg mg/l	Sr mg/l	Ca mg/l	Cl mg/l	F mg/l	Br mg/l	NO3 mg/l	SO4 mg/l	Field HCO3 mg/l	Lab HCO3 mg/l	Data Code
YM-7A	6/22/88	BEG	7.2	29.5	20.2	305.0	20.30	26.6	1.23	69.6	316.0	3.20	0.79	0.80	161	439.20	393	BEG-47
YM-7A	11/19/88	BEG	7.0	31.8	21.6	308.0	19.80	26.4	1.22	69.0	614.0	2.57	0.71	0.80	181	462.38	387	BEG-47
YM-7A	3/4/89	BEG	7.1	33.4	20.3	303.0	20.40	25.0	1.15	71.2	620.0	2.32	0.54	1.42	202	379.80	386	BEG-47
YM-7A	5/24/59	BEG	7.2	33.4	21.2	298.0	21.10	24.5	1.26	71.3	319.0	2.66	0.54	1.99	171	406.26	389	BEG-47
YM-8	11/20/88	BEG	7.2	25.7	12.6	285.0	3.80	28.8	1.67	65.1	96.3	2.97	0.88	0.80	431	581.96	391	BEG-47
YM-8	5/25/89	BEG	7.2	26.8	13.0	280.0	3.57	31.3	1.99	77.9	95.4	2.71	0.66	0.96	445	433.10	398	BEG-47
YM-18	2/28/89	BEG	7.5	28.2	12.4	934.0	17.50	26.7	2.11	74.6	464.0	4.85	2.33	24.80	1170	369.97	389	BEG-47
YM-18	5/24/89	BEG	7.4	29.1	13.3	954.0	17.40	33.8	2.58	92.8	445.0	5.32	2.72	25.30	1380	446.52	387	BEG-47
YM-18	7/28/89	BEG	7.2	29.0	13.1	962.0	16.50	29.5	2.07	79.0	457.0	6.32	2.31	24.80	1233	477.00	394	BEG-47
YM-19	2/2/89	BEG	7.1	28.4	14.7	645.0	33.10	32.6	2.11	95.7	547.0	3.88	1.97	5.39	683	356.53	353	BEG-47
YM-19	5/26/89	BEG	7.3	29.3	15.2	625.0	33.30	32.2	2.07	99.9	483.0	4.89	1.34	5.29	671	384.92	347	BEG-47
YM-19	7/29/89	BEG	7.3	29.5	15.9	652.0	30.80	29.2	1.99	91.1	509.0	5.35	2.31	5.52	659	396.00	352	BEG-47
YM-63	8/19/89	BEG	7.1	30.4	14.1	1200.0	28.60	59.3	4.36	180.0	779.0	6.50	3.91	46.30	1716	306.22	315	BEG-47
48-45-602	2/9/71	TDWR	7.6			520.0	36.00	47.0		109.0	590.0	3.80		3.20	434		434	TDWR-89
48-45-603	8/9/88	BEG	7.4	27.4	16.0	577.0	20.90	41.1	2.41	91.2	546.0	4.08	1.12	3.91	485	477.00	405	BEG-47
48-53-501	1/12/88	BEG	7.2	23.2		751.0	2.03	34.1	4.79	85.6	149.0	2.99	0.7	0.10	1170	702.72	649	BEG-47
48-53-501	5/25/88	BEG	7.0	25.1	16.7	779.0	2.08	36.1		92.3	154.0	2.19	1.48	0.10	1250	670.15	627	BEG-47
48-53-802	6/25/88	BEG	7.2	23.3	20.8	64.1	1.57	12.9	0.82	112.0	34.8	1.35	0.32	7.73	146	328.79	321	BEG-47
48-53-803	5/27/88	BEG	7.2	20.6	25.7	51.7	1.69	13.9	1.01	141.0	22.3	1.32	0.25	1.86	158	361.00	361	BEG-47
48-53-804	8/22/69	GS	7.6	26.0	19.0	100.0		25.0		76.0	39.0	1.80		3.10	190		316	TDWR-89
48-54-401	9/26/64	TDWR	7.5			540.0		36.0		97.0	650.0	4.50		0.40	362		356	TDWR-90
48-54-402	7/22/39	GS		38.0		303.0		9.8		27.0	202.0			8.40	184		346	TDWR-90
48-54-404	10/29/87	BEG	7.2	32.0		402.0	22.60	13.4		44.4	357.0	5.05		15.10	289	384.54	328	BEG-47
48-54-404	5/31/88	BEG	7.2	32.0	22.9	433.0	25.00	14.2	1.50	51.3	361.0	4.93	0.87	13.10	332	356.00	370	BEG-47
48-54-502	8/12/88	BEG	7.5	26.8	13.3	582.0	27.00	25.5	2.68	77.0	600.0	5.00	5	5.00	410	449.57	597	BEG-47
48-54-503	8/22/68	GS	7.8	28.0	27.0	610.0		26.0		86.0	650.0	4.90		4.20	390		372	TDWR-90
48-54-801	9/14/68	GS	8.0	22.0	19.0	600.0		30.0		81.0	610.0	4.80		1.10	400		426	TDWR-90
48-62-TEX	3/2/89	BEG	7.8	24.0	14.1	163.0	2.88	27.4	1.87	64.3	70.0	2.19	0.55	5.69	277	312.93	301	BEG-47
48-62-TEX	5/26/89	BEG	7.6	25.3	15.4	165.0	2.20	26.4	2.05	67.3	67.8	2.24	0.67	6.07	265	333.06	303	BEG-47
48-62-TEX	7/27/89	BEG	8.2	27.1	28.8	185.0	8.65	5.9	0.59	10.8	24.6	5.49	0.17	0.23	128	339.00	315	BEG-47
48-63-302	8/30/68	GS	7.6	26.0	27.0	154.0		44.0		41.0	58.0	1.10		6.50	185		410	TDWR-90

BEG=Bureau of Economic Geology GS=Geological Survey TDWR-89, 90=TDWR Report

TDWR=Texas Water Development Board BEG-47=Daring, et.al (1994)

Table 2. Example of hydrochemical database.

collected at 3 tanks, 2 retention ponds, and at Grayton Lake, and 4) when standing water is available, quarterly sampling of gross alpha, gross beta, tritium, carbon-14, and suspended particles in the water.

I utilized data from the hydrochemical database to construct a hydrochemical facies map of the site area (figure 4). By comparing concentration levels of cations and anions, I was able to construct areas of dominant hydrochemical facies. For instance, the groundwater surrounding Sierra Blanca is a Na-Cl dominated facies, while a Ca-HCO_3 facies characterizes much of the groundwater in the Eagle Mountains (figure 4). In addition to the hydrochemical facies map, I created a total TDS concentration map that aided in delineating areas of recharge and discharge (figure 6). Recharge areas contain Ca as the dominant cation and HCO_3 or CO_3 as the dominant anion, and are also characterized by low TDS concentrations (<1000 mg l^{-1}). Discharge zones are characterized by Na as the dominant cation, SO_4 or Cl as the dominant anion, and high TDS concentrations (>3000 mg l^{-1}). The shift in facies is a result of changing lithology from Cretaceous limestones in the central Diablo Plateau to Permian limestones in the northeast (containing Ca, SO_4, and Cl) and to clayey silts and sands in the alluvial aquifer. The high sulfate waters change from $CaSO_4$ to $NaSO_4$ as they flow because Na exchanges for Ca in a cation exchange reaction. This is especially true when waters flow through clays, due to the greater amount of Na in clays than in limestones.

Summary

Through my work at the BEG I designed a hydrogeologic database and a hydrochemical database to be used for the monitoring data from the Texas Low-Level Radioactive Waste Facility. The main goal I accomplished was to set up a system that can be used to compare pre- and post-facility operation data. I reviewed each data parameter in the databases and found that future monitoring research can include

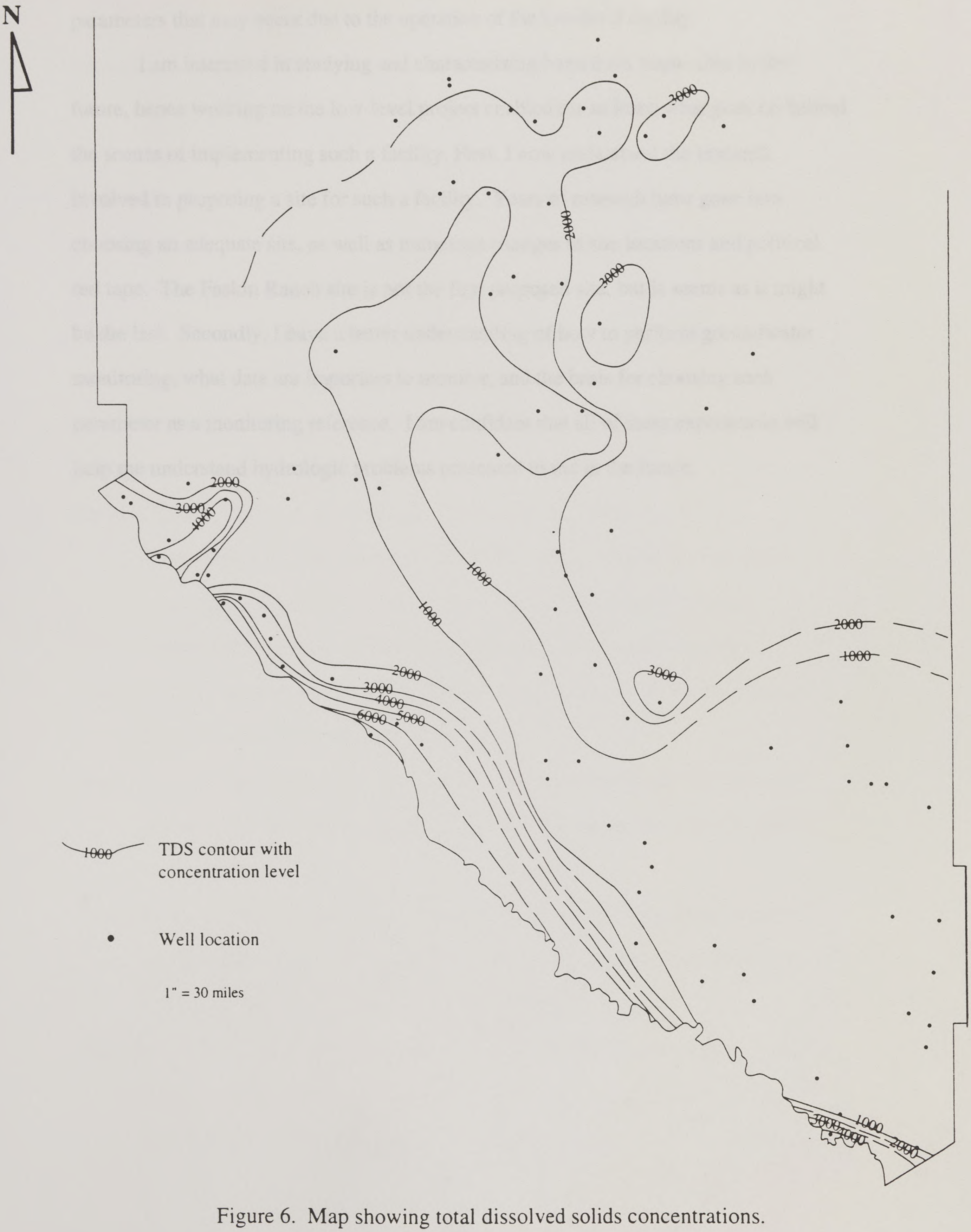

Figure 6. Map showing total dissolved solids concentrations.

constructing graphs of different data versus time to linearly visualize changes in these parameters that may occur due to the operation of the low-level facility.

I am interested in studying and characterizing hazardous waste sites in the future, hence working on the low-level project enabled me to learn what goes on behind the scenes of implementing such a facility. First, I now understand the research involved in proposing a site for such a facility. Years of research have gone into choosing an adequate site, as well as numerous changes in site locations and political red tape. The Faskin Ranch site is not the first proposed site, but is seems as it might be the last. Secondly, I have a better understanding of how to perform groundwater monitoring, what data are important to monitor, and the basis for choosing each parameter as a monitoring reference. I am confident that all of these experiences will help me understand hydrologic problems presented to me in the future.

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Appendix A

Assessing water level depletions in the Texas Ogallala Aquifer

The BEG is assessing how the Panhandle Groundwater District #3 (PGWD#3) assigns water level depletions to properties with the aim of developing a more accurate, rigorous, and automated method for these calculations and to create groundwater depletion maps of the PGWD#3. Groundwater depletion maps document and quantify the decrease in groundwater resources in the PGWD#3 by monitoring the historically lowest water levels in the Ogallala Aquifer. These are used to assign water level declines used by eligible land owners for Federal tax credit. The procedures used in making these depletion maps need to be accurate and fair because area ranchers use these maps for these assignments and in documenting groundwater reserves. Currently, water levels are measured, plotted on a hydrograph, and then smoothed with a back-calculated 5 year average to guide water level assignments used in generating the maps. Water depletion levels are then estimated visually. This is not only inaccurate, but may also underestimate depletion levels. Water level measurement errors may also occur with this process. Highly fluctuating water levels indicate these errors on a hydrograph (figure 7). Therefore, assigning depletion levels based on field measurement values may give an erroneous decline (Mullican and Mace, 1996).

I examined hydrographs from wells in Carson, Armstrong, Donley, Roberts, and Gray counties in order to check the accuracy and behavior of water level measurements. I looked at measured water level fluctuations and then compared them to the overall trend in water levels for that particular well. Wells showing abnormal spike measurements were noted for later examination and re-measurement. Secondly, I looked to see if the assigned depletion levels were on, above, or below the actual and average water level measurements. Preparation of an automatic method of assigning water level depletions will use this information to improve the accuracy of the depletion level predictions.

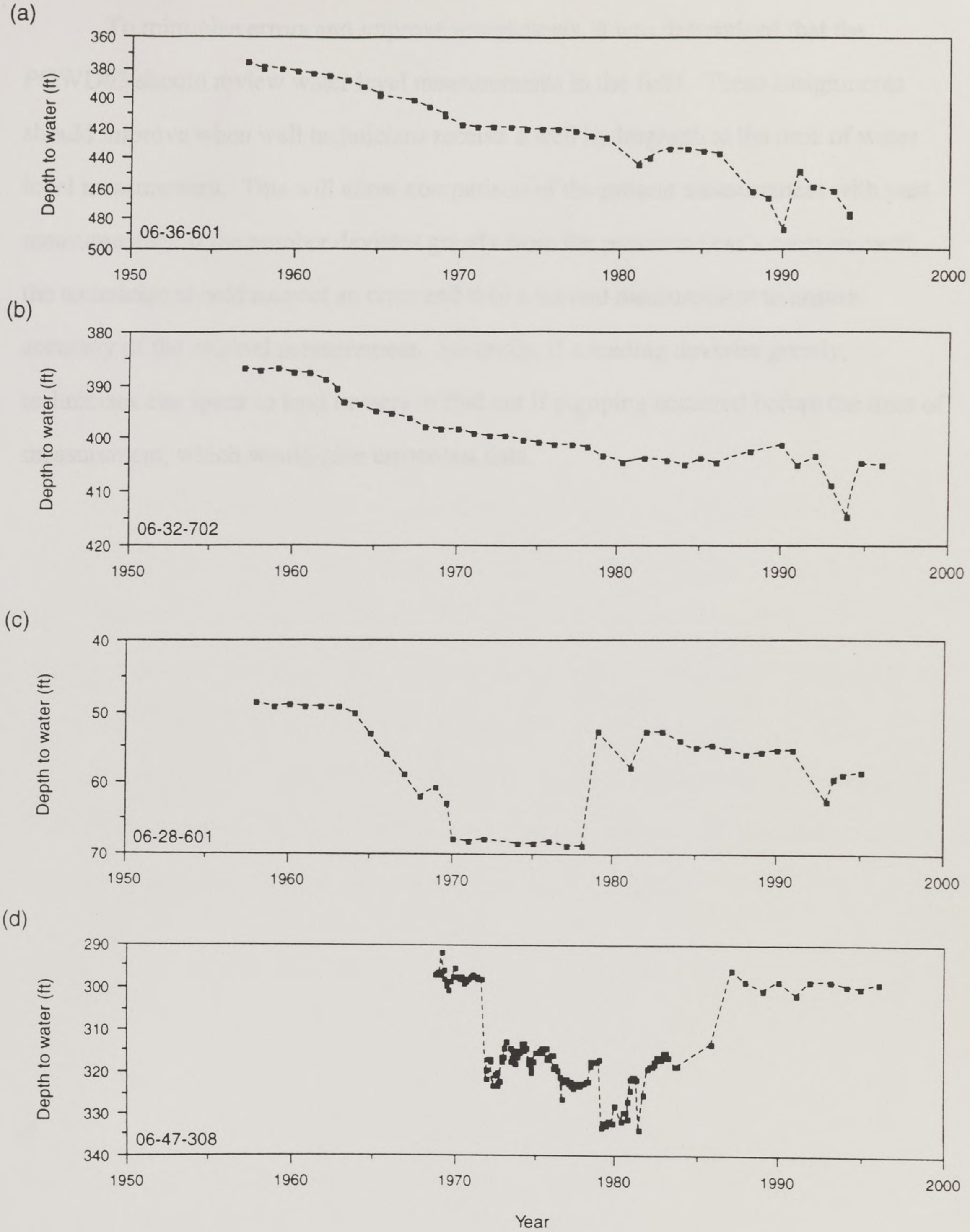

Figure 7. Hydrographs for four wells in the Ogallala aquifer (from Mullican and Mace, their figure 3).

To minimize errors and improve assignments, it was determined that the PGWD#3 should review water level measurements in the field. These assignments should improve when well technicians receive a well hydrograph at the time of water level measurement. This will allow comparison of the present measurement with past measurements; if the number deviates greatly from the previous year's measurement, the technician should suspect an error and take a second measurement to ensure accuracy of the original measurement. Secondly, if a reading deviates greatly, technicians can speak to land owners to find out if pumping occurred before the time of measurement, which would give erroneous data.

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When I entered the geology department at UT in 1993, I had no idea that I would grow to love the science as much as I do now. This is partly because the science is so interesting, but also because I had great teachers to look up to and learn from. I'd like to thank all of my professors, from Dr. Lundelius to Dr. McBride, but most especially I thank Dr. Jack Sharp, for teaching me and giving me the opportunity to succeed when others had not. Your confidence and support in me has made a lasting impression and is something I will never forget.

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